Rec'd PCT/PTO 26 SEP 2001
09/937399

WHIPSTOCK CASING MILLING SYSTEM

This invention relates to a whipstock casing milling system, and more particularly to such a system in which a window mill is secured to the whipstock so that the system may be run into a well, set and operated to open a window in the casing in a single trip.

A one trip casing milling system as described above is shown in our British patent publication GB2312702A. In the system described in this patent specification, a window mill is secured by means of a shear bolt to the end of the whipstock. The window mill includes a tapered end, the taper of which matches the ramp angle of the end portion of the whipstock. This ramp angle is relatively steep (typically 15°) so that, at the start of casing milling, the window mill is forced rapidly into the casing in order to form an initial opening.

Whilst this system for effecting the initial break through of the casing offers considerable advantages over the prior art, the arrangement does have the disadvantage that the area of contact between the tapered portion of the window mill and the initial steep ramp surface on the whipstock (i.e. the bearing area) decreases as the window mill begins to penetrate the casing. Although the whipstock ramp continues to apply a lateral force to the window mill the reaction force on the whipstock becomes progressively concentrated on a small region of the ramp face. Even though the whipstock ramp may be hardened, the fact that the reaction force from the window mill is concentrated on a relatively small area of the ramp tends to lead to wear of the ramp. This wear is particularly noticeable at the point where there is a change of whipstock angle at the bottom end of the initial steep ramp portion. Immediately before the casing milling tool begins to run down the relatively shallow angled (or parallel) portion of the whipstock below the steep ramp, the entire reaction force applied by the window mill to the whipstock is concentrated in this small area. Even if the whipstock is extensively hardened in this area, wear will

ART 34 AMDT

inevitably occur. One result of this wear is that the window in the casing is not opened up as quickly as might be expected from the initial (pre-wear) profile of the whipstock. One prior art system according to the preamble of the appended claims (disclosed under international publication number WO 98/04804) provides a partial solution to this problem, but does not necessarily allow prevention of undesirable ramp wear under given conditions.

We have now devised a complete solution to the aforementioned problem.

A first aspect of the present invention provides a whipstock casing milling system according to the appended independent claim 1. A further aspect of the present invention provides a whipstock casing milling system according to the appended independent claim 9. A further advantageous feature is defined in the appended dependent claims 2 and 10. A yet further aspect of the present invention provides a method of using a window casing milling system according to appended independent claim 8.

The protrusion will, in practice, be milled partially or completely away during the casing milling operation. However, the existence of the protrusion prevents the excessive damage to the relatively steep ramp surface of the whipface such as has occurred in the prior art. The protrusion may be of any suitable material, for example steel of a suitable grade.

Ideally, the protrusion is provided on the relatively shallow ramp surface or parallel surface of the whipface. Preferably, the protrusion is removably secured to the whipface. The protrusion may be movably secured by means of at least one threaded fastener. It is further preferable for the

protrusion to comprise a surface which is ramped at the same angle relative to the longitudinal axis of the whipstock as the relatively steep ramp surface. The ramped surface of the protrusion and the relatively steep ramp surface are ideally ramped at an angle of 15° relative to the longitudinal axis of the whipstock.

The invention will be better understood from the following description of a preferred embodiment thereof given by way of example only, reference being had to the accompanying drawings, wherein:

Figure 1 corresponds to Figure 4 of the above mentioned GB2312702A;

Figures 2, 3 and 4 illustrate the milling apparatus of Figure 1 in use during a casing milling operation;

Figure 5 illustrates the improvement according to the present invention; and

Figures 6, 7 and 8 illustrate the milling apparatus of Figure 5 in use during a casing milling operation.

Turning firstly to Figure 1, there is shown a portion of the casing milling system of GB2312702A. Reference should be had to the text of this patent publication for further description of the illustrated system. For the present purposes however, it is sufficient to note that the illustrated system comprises a window mill 32 which is secured to a whipstock 44 by a shear bolt 39. The whipstock has a whipface which includes a relatively steep starter surface 45 followed by a vertical surface 46 (i.e. a surface parallel to the longitudinal axis of the casing). The relatively steep starter surface 45 meets the vertical surface 46 at a transition point A. In use, after the illustrated casing milling system has been run in hole, a packer or anchor secured to the bottom of the whipstock is set and the window mill 32 is released by shearing the shear bolt 39. The drill string is then rotated and weight applied to the window mill 32. The window mill runs up the relatively steep starter surface 45 on the

whipstock and is thereby forced laterally into the casing on the side thereof opposite the whipstock. The casing is disintegrated and the window mill moves downwardly.

It will be appreciated that immediately before the window mill moves on to the vertical section 46 of the whipface, the entire reaction force of the window mill onto the whipface is taken by the portion of the starter surface 45 immediately adjacent the juncture A. This results in wear of the whipface at this point with the result that the window mill is not forced cleanly through the casing as intended in the original design.

Indeed, wear of the steep starter surface 45 typically begins well before the window mill 32 progresses onto the vertical surface 46. This is illustrated in Figures 2, 3 and 4 of the accompanying drawings. In Figure 2, the window mill 32 is shown at the foot of the steep starter surface 45 prior to commencing cutting of the well casing. As the window mill 32 is pushed up the starter surface 45, the bearing area (i.e. the area of contact between the window mill and the starter surface) reduces. The lateral reaction force applied by the well casing onto the window mill does not reduce however and indeed tends to increase with the depth of cut. The stress in the starter surface 45 produced by the window mill 32 is a function of the lateral reaction force and the bearing area. The dependency is such that the stress in the starter surface 45 increases both as the lateral reaction force increases and as the bearing area decreases. Accordingly, as the window mill 32 moves up the starter surface 45, the stress in the starter surface 45 will increase until a critical level is attained, at which point, the starter surface 45 will begin to disintegrate. The minimum bearing area Z before disintegration of the starter surface 45 begins is shown in Figure 3. As the window mill 32 progresses up the starter surface 45 so as to reduce the bearing area below the minimum value, disintegration of the whipstock begins and the angle of the starter surface 45 is effectively reduced. An undercutting of the well casing results. Depending upon the operational

circumstances (including, for example, the relative hardness of the whipstock and the well casing), the angle of the starter surface 45 can, in an extreme case be reduced to zero (see Figure 4). In this event, a window in the well casing will not be formed.

Sub B1 Referring now to Figure 5, the above outlined problem is solved by means of a protrusion B which is provided on the whipface immediately below the lower end of the starter surface 45. The protrusion B in effect extends the starter surface 45 downwardly of the well. The effect of the protrusion is to provide extra support for the reaction forces imposed on the whipface by the window mill and thereby reduce or prevent the undesired wearing away of the starter surface 45 itself. In practice, the protrusion will in general be milled away in use by the window mill. However, the existence of the protrusion ensures that adequate lateral movement of the window mill is achieved before the window mill starts travelling down the vertical surface 46. The protrusion can be of any suitable material and can be secured to the whipface by any convenient means, for example by means of screws or by welding.

Use of a whipstock casing milling system according to the present invention is shown in Figures 6, 7 and 8 of the accompanying drawings. In Figure 6, the window mill 32 is shown at the foot of the steep starter surface 45 prior to commencing cutting of the well casing. As the window mill 32 is pushed up the starter surface 45, the bearing area initially remains constant due to the provision of the protrusion B. It is only as the window mill 32 is pushed beyond the extended starter surface 45 (see Figure 7) that the bearing area begins to reduce. This reduction in bearing area contributes to an increase in the stress within the starter surface 45 and the extension provided by protrusion B. However, the protrusion B is sized so that starter surface 45 is sufficiently extended for attainment of the critical stress level to be delayed until the required lateral displacement of the window mill 32 has occurred. As intimated ____________

above, this required lateral displacement occurs when the window mill 32 (specifically the largest outer diameter of the window mill 32) reaches the juncture A between the vertical section 46 of the whipface and the (unexteneded) starter surface 45.

The extension to the starter surface 45 provided by the protrusion B is sized so as to provide a contact area with the window mill 32 substantially equal to the minimum bearing area Z indicated in Figure 3 (assuming the protrusion B is of an identical material to that of the whipstock and the forces exerted by the window mill 32 having reached juncture A (see Figure 7) are identical to those exerted by the window mill 32 located in the critical position shown in Figure 3). A skilled person will be capable of calculating the precise dimensions of the protrusion B in view of known operating circumstances.

Once the window mill 32 has progressed up the starter surface 45 to the position indicated in Figure 7, the lateral reaction forces exerted by the window mill 32 in cutting into the wellbore side are borne solely by the protrusion B. The arrangement is such that the critical stress level is not attained until the window mill 32 progresses to or beyond the position of Figure 7. When the critical stress level is attained, the protrusion B is either partially or wholly (as shown in Figure 8) milled away. The starter surface 45 and vertical section 46 of the whipface remain substantially undamaged and a window is opened as required. The whipstock itself may be used in future operations with a replacement protrusion B.

The present invention is not limited to the specific embodiment described above. Alternative arrangements and suitable materials will be apparent to a reader skilled in the art.